National University of Sciences and Technology (NUST)

School of Electrical Engineering and Computer Science (SEECS)

Digital Image Processing

Khawar Khurshid

Intensity Transformations

Look-up Tables

Linear Contrast Stretch

Piece-wise Contrast Stretch

Histogram Equalization

Power Law

Log Transform – Gamma correction

Dynamic Range vs Contrast

Dynamic Range

Minimum Possible Intensity to Maximum Possible Intensity

Contrast

Minimum Image Intensity to Maximum Image Intensity

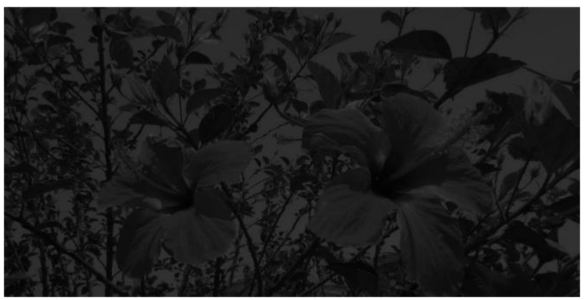
What do you think is the dynamic range of this image?

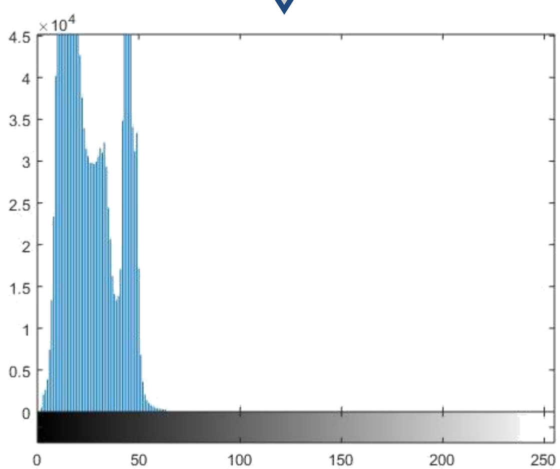
What is the approximate contrast range?

Dynamic Range vs Contrast

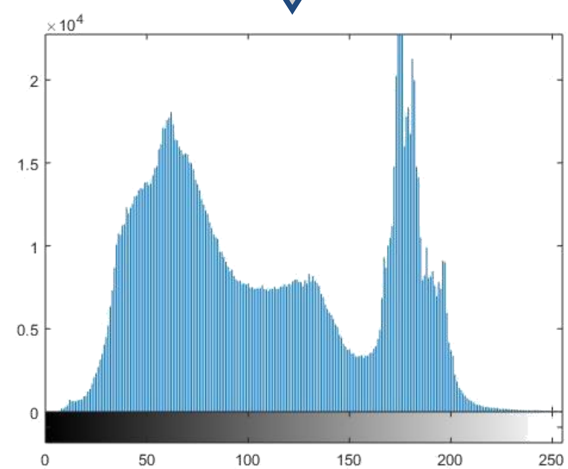
Dynamic range (8-bit) = $max - min = 255 - 0 = 255$

Contrast = 0 - 55

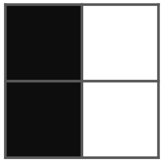
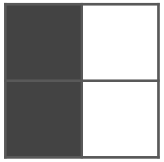
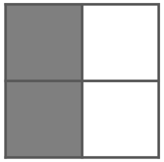
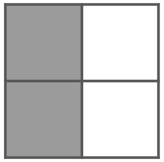




Contrast = 0 - 255



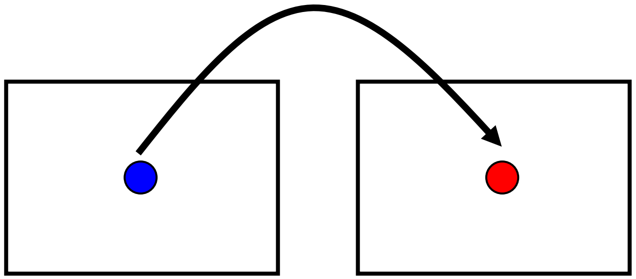
Dynamic Range vs Contrast

X Y	Dynamic Range	Contrast
	255	0-255
	255	50-255
	255	75-255
	255	100-255

Intensity Transformations

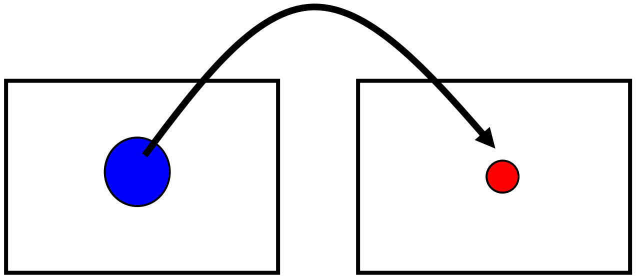
- Point/Pixel operations

  Output value at specific coordinates (x,y) is dependent only on the input value at (x,y)



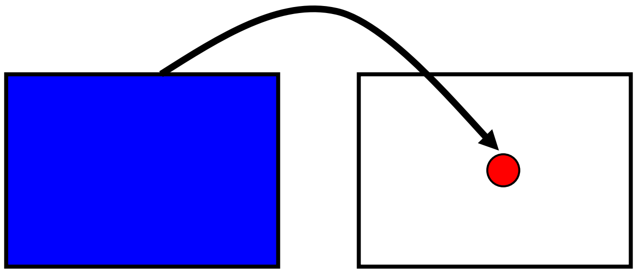
- Local operations

  The output value at (x,y) is dependent on the input values in the neighborhood of (x,y)



- Global operations

  The output value at (x,y) is dependent on all the values in the input image



Intensity Transformations

Basic Concept

Most spatial domain enhancement operations can be generalized as:

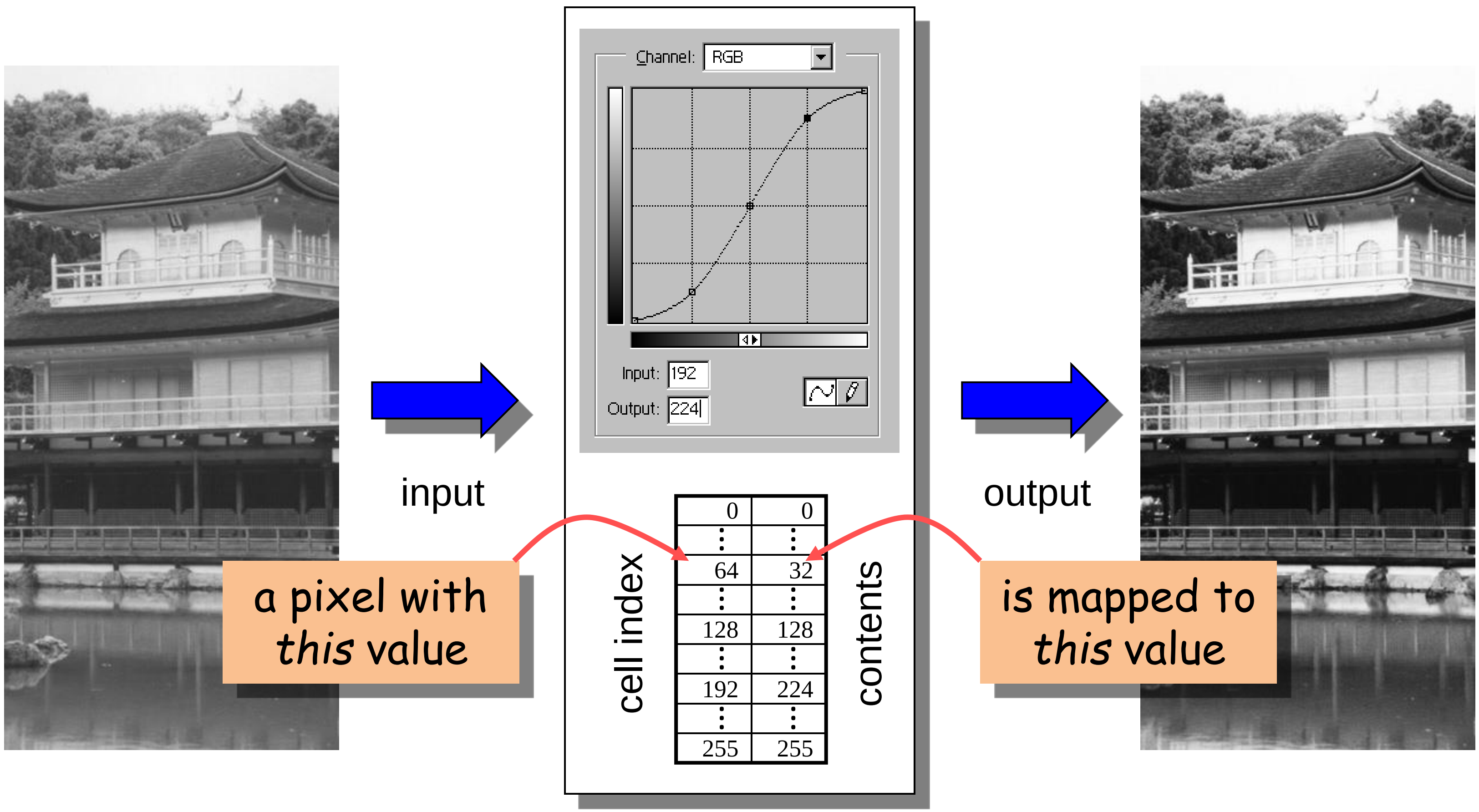
$$g(x, y) = T\left[f(x, y)\right]$$

$f(x, y)$ = Input image

$g(x, y)$ = Processed/output image

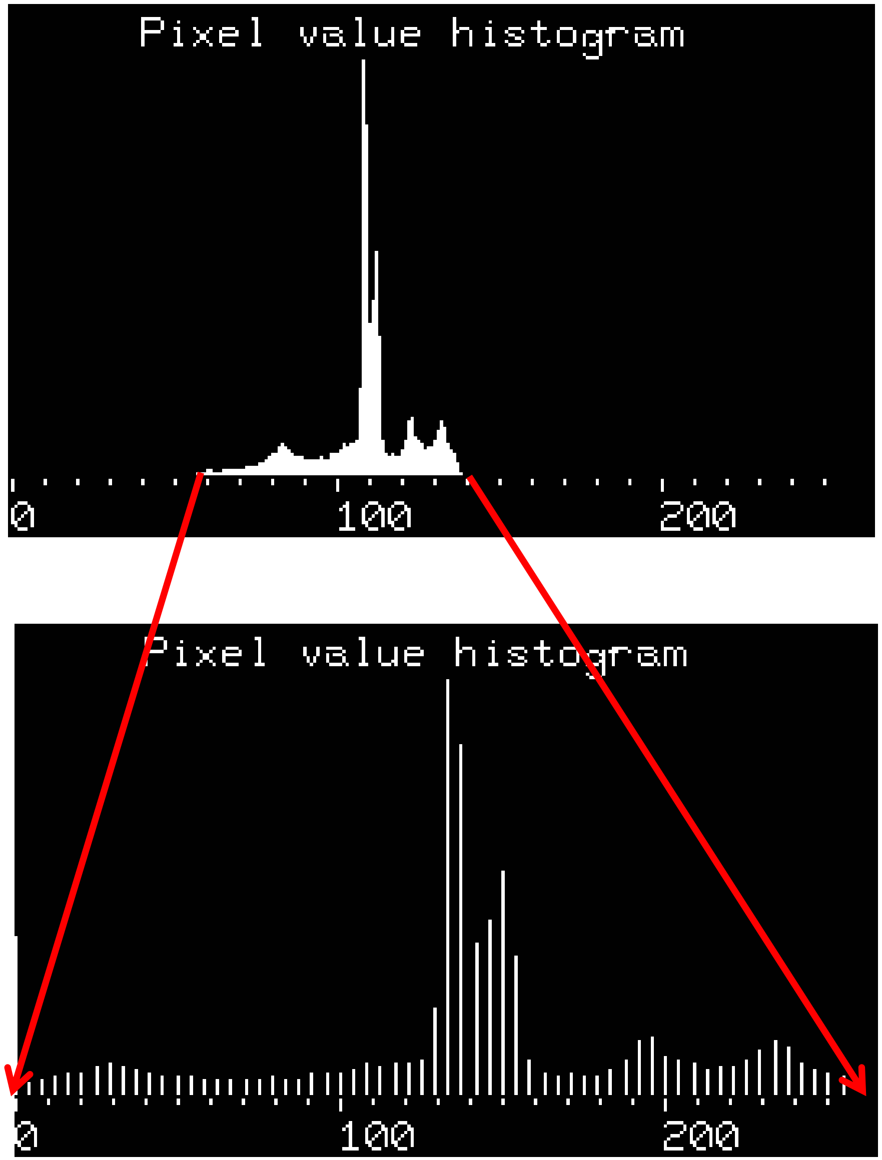
T = Operator defined over some neighbourhood of (x, y)

Look up Table Mapping



Point Processing using Look-up Tables

Linear Contrast Stretch

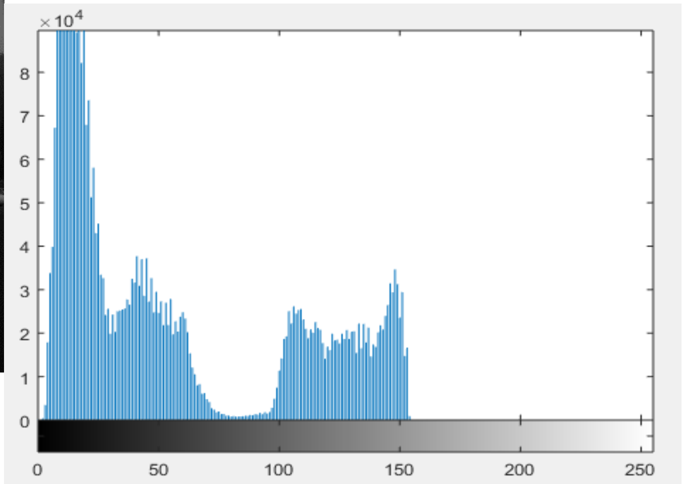


Linear Contrast Stretch

Original Image

Linear Contrast Stretch

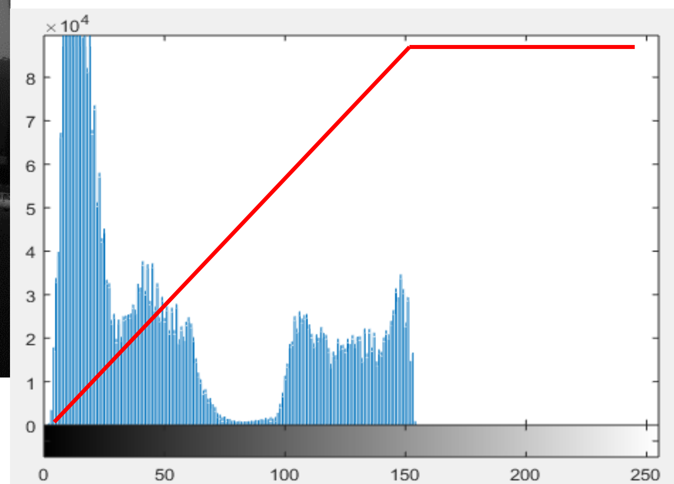
Original Image



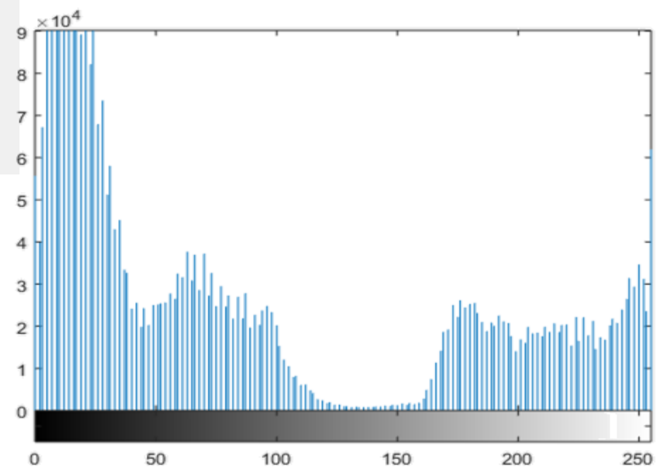
Histogram

Linear Contrast Stretch

Original Image



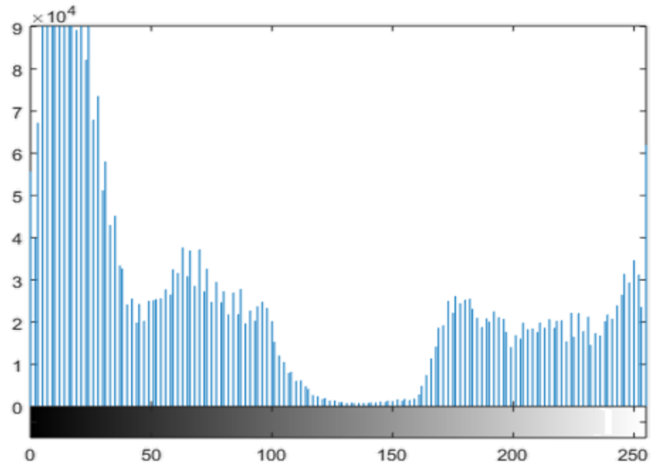
Histogram



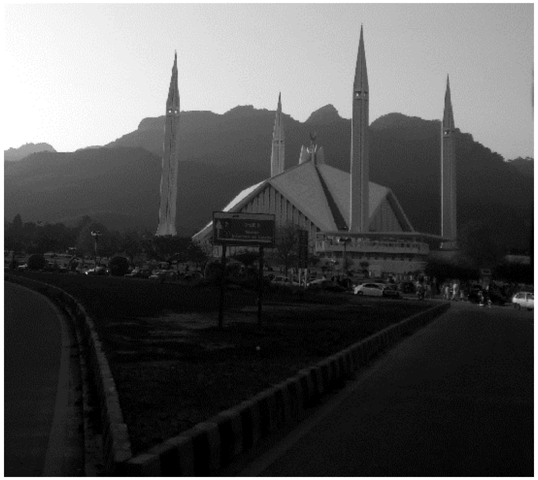
Linear Contrast Stretching

Linear Contrast Stretch

Original Image



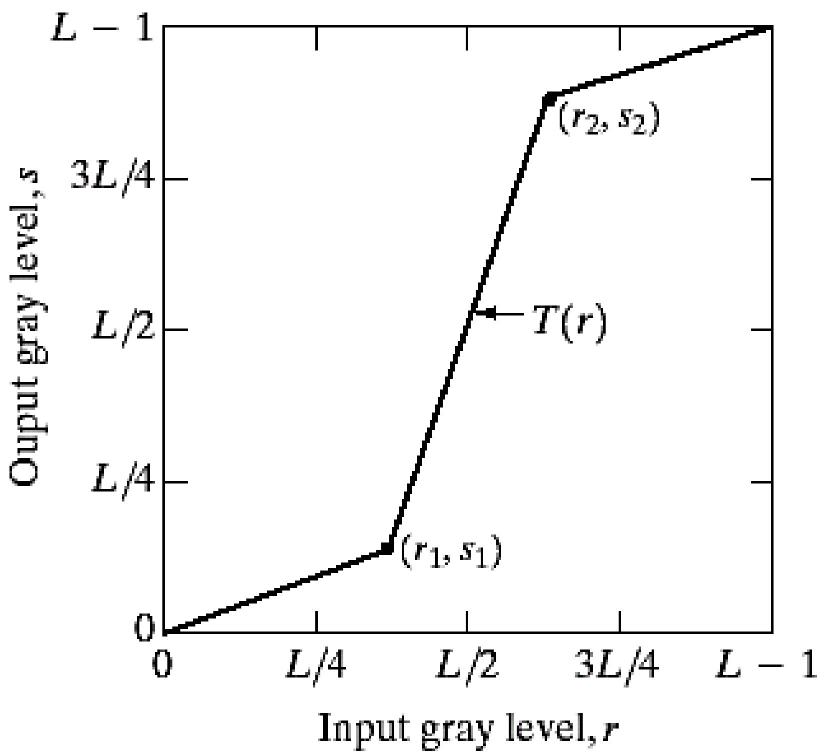
Linear Contrast Stretching



Output Image

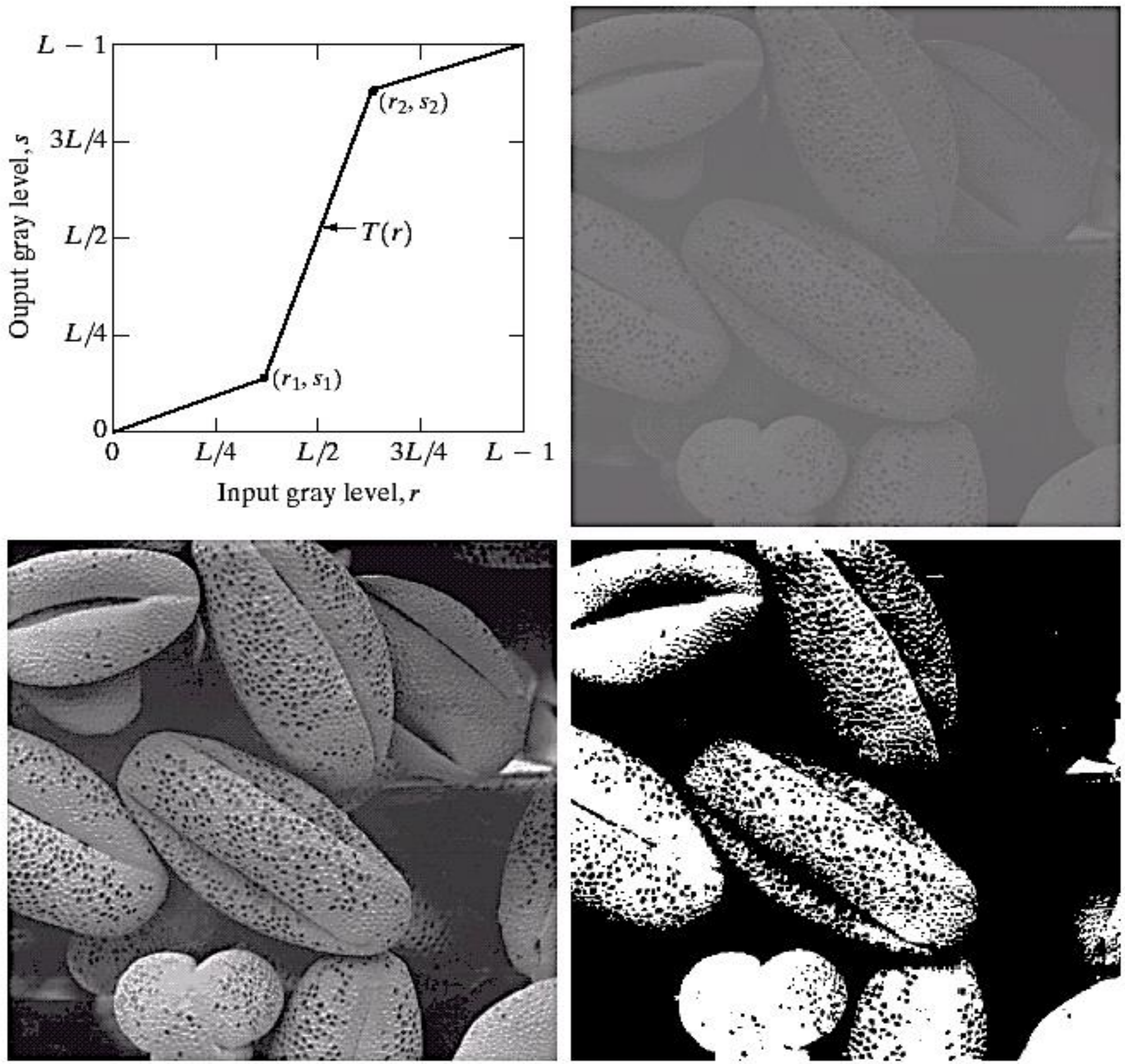
Piece-wise Contrast Stretching

- Objective
  - Increase the dynamic range of the gray levels for low contrast images
- Rather than using a well defined mathematical function we can use arbitrary user-defined transforms



- If $r_1 = s_1$ & $r_2 = s_2$, no change in gray levels
- If $r_1 = r_2$, $s_1 = 0$ & $s_2 = L-1$, then it is a threshold function. The resulting image is binary

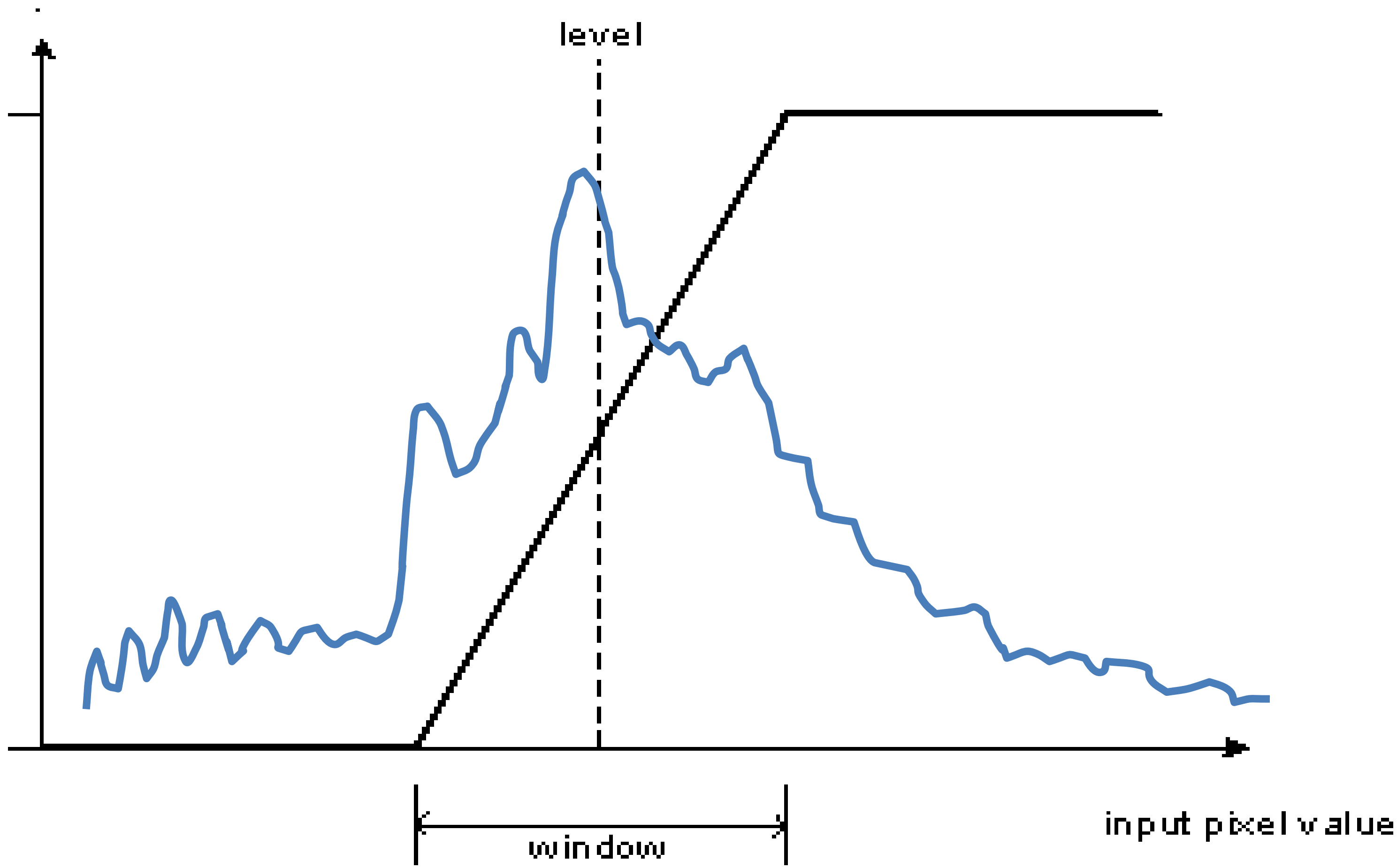
Piece-wise Contrast Stretching



a b
c d

FIGURE 3.10 Contrast stretching. (a) Form of transformation function. (b) A low-contrast image. (c) Result of contrast stretching. (d) Result of thresholding. (Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra, Australia.)

Window Level

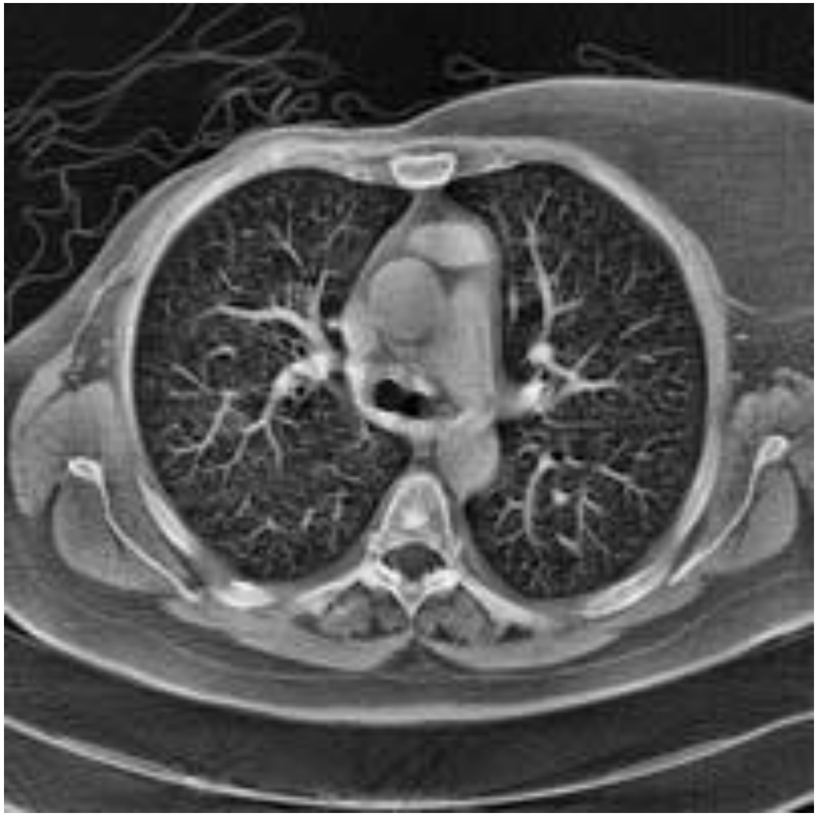


Selecting a Window of the intensity values to be enhanced.

Window Level

Window of dark intensity values are enhanced.

Window Level



Intensity values corresponding to the Lungs is enhanced.

Histogram
Of
Images

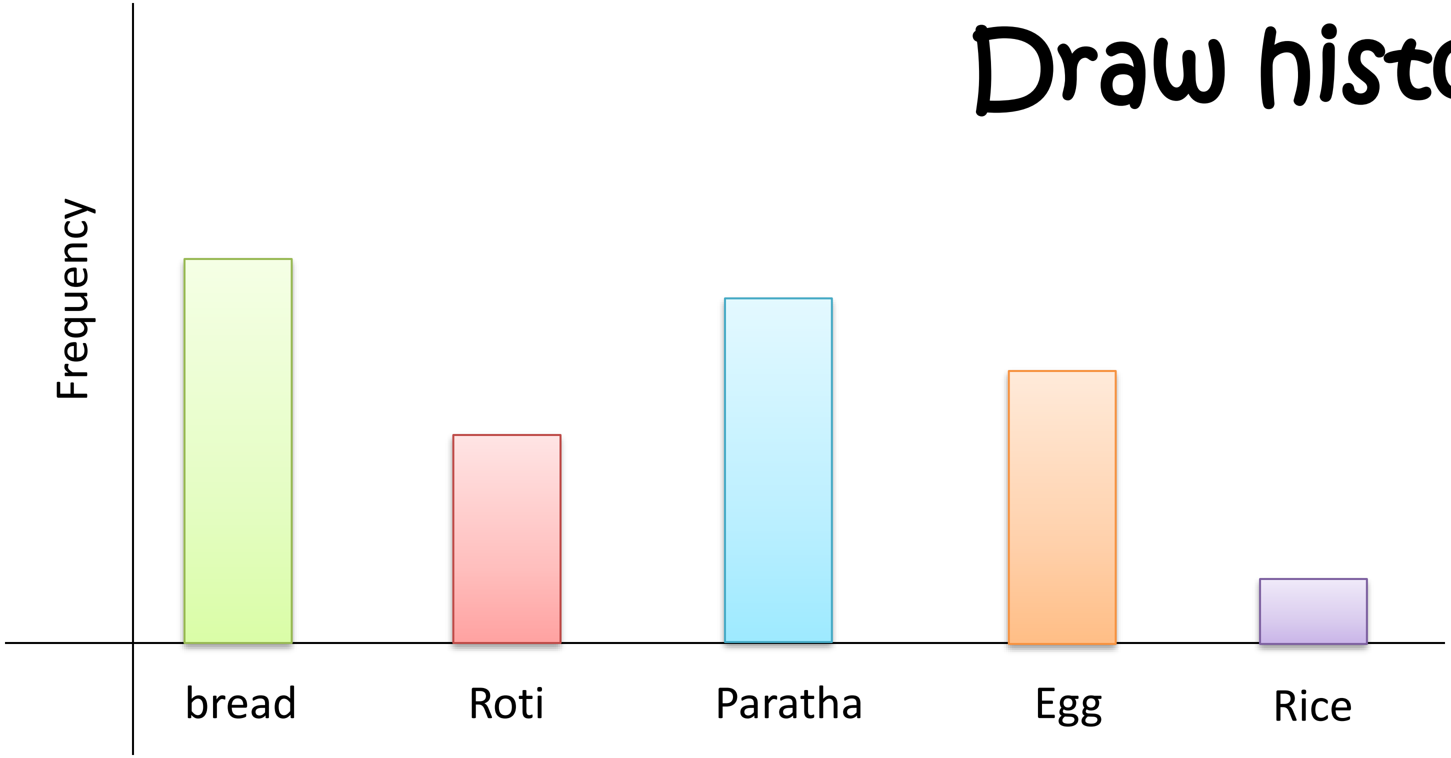
Activity

How many of you eaten egg, roti, paratha, bread or rice in breakfast?

Activity

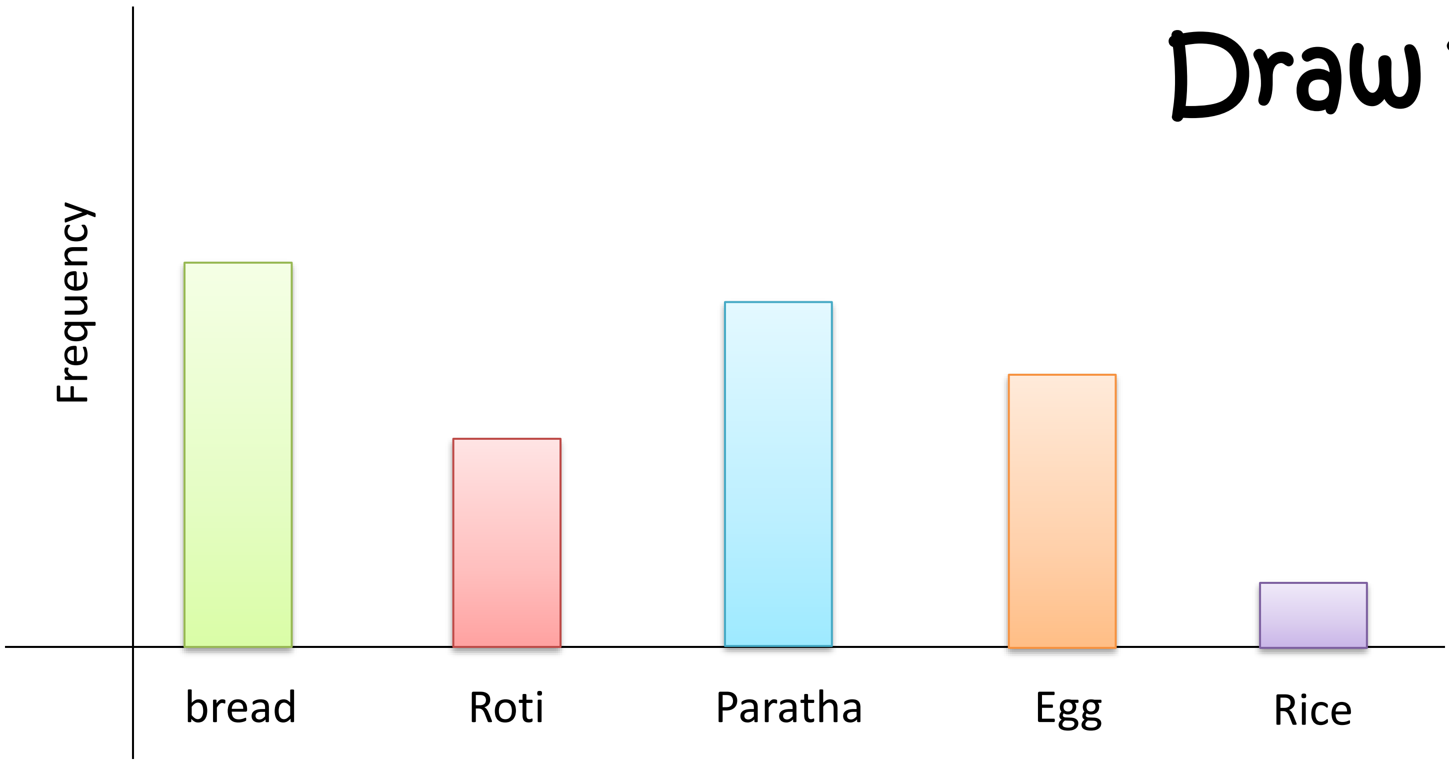
How many of you eaten egg, roti, paratha, bread or rice in breakfast?

Draw histogram



Activity

How many of you eaten egg, roti, paratha, bread or rice in breakfast?



Draw PDF

Khawar Khurshid

Image Histogram

- The histogram of a digital image with gray values is the discrete function

$$p(r_k) = \frac{n_k}{n} \qquad k = 0,1,\ldots,L-1$$

- N_k : Number of pixels with gray value r_k
- N : Total number of pixels in the image

- The function $p(r_k)$ represents the fraction of the total number of pixels with gray value r_k.

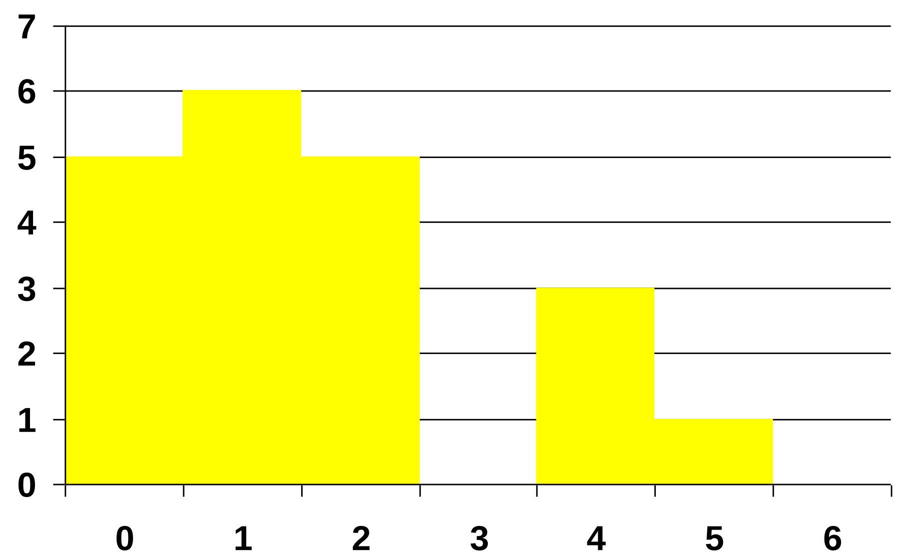
Image Histogram

The (intensity or brightness) histogram shows how many times a particular grey level (intensity) appears in an image.

For example, 0 - black, 255 – white

0	1	1	2	4
2	1	0	0	2
5	2	0	0	4
1	1	2	4	1

Image



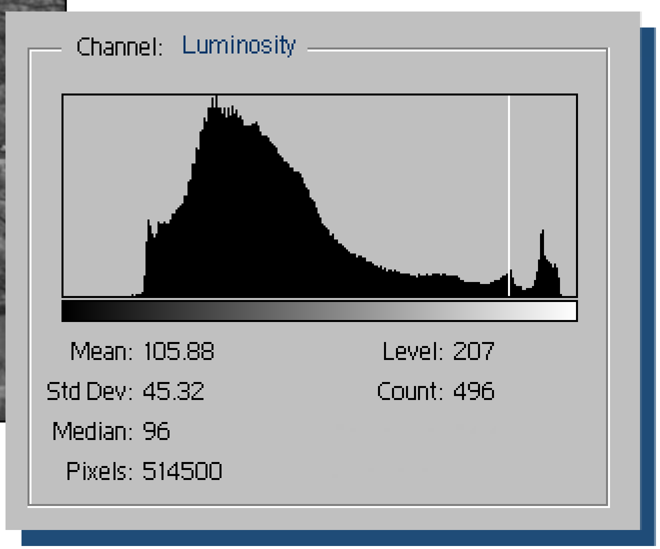
Histogram

Histogram Calculation

```
I = imread('rain.jpg');
G = rgb2gray(I);
[x,y] = size(G);

H = zeros(1,256);

  for i=1:x
      for j=1:y
          H(G(i,j)+1) = H(G(i,j)+1) + 1;
      end
  end

stem(H);
```

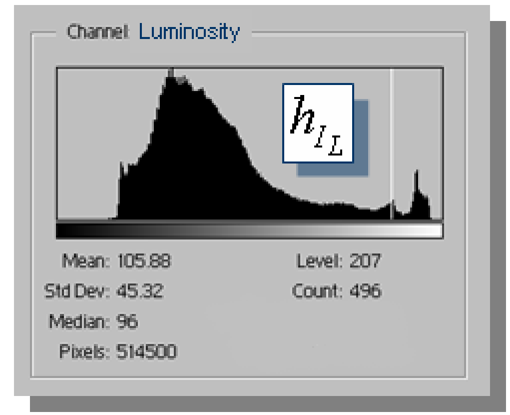
Histogram – Gray Scale Image

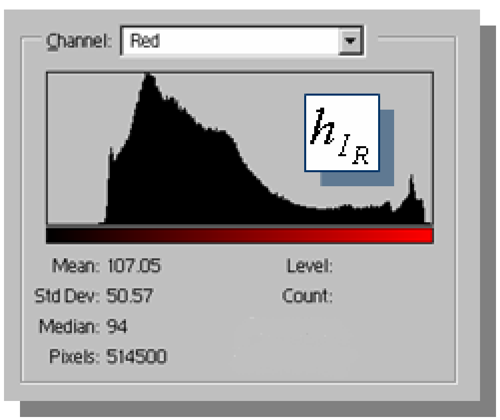
$$h_I(g) = \text{ the number of pixels in } I \text{ with graylevel } g.$$

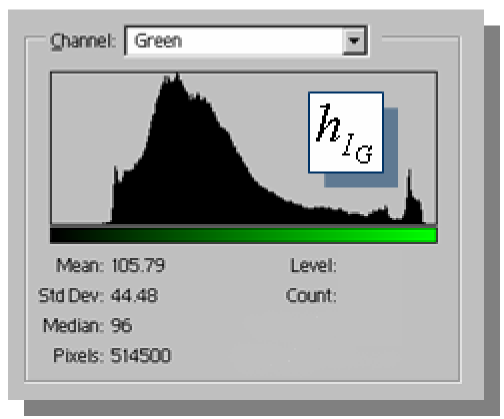


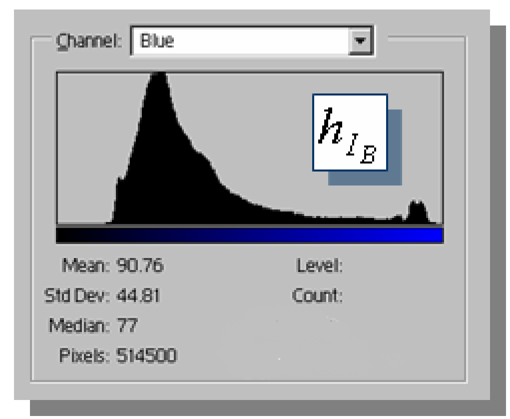
Histogram – Color Image

There is one histogram per color band R, G, & B. Gray histogram is from 1 band = (R+G+B)/3









Histogram – Color Image

Histogram to CDF

0	0	0	2	2
1	1	1	2	2
5	5	5	3	3
5	6	6	4	3
4	4	4	4	4

$5 \times 5 \; matrix$

Histogram to CDF

0	0	0	2	2
1	1	1	2	2
5	5	5	3	3
5	6	6	4	3
4	4	4	4	4

$5 \times 5 \; matrix$

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1	1	1	2	2
5	5	5	3	3
5	6	6	4	3
4	4	4	4	4

$5 \times 5 \; matrix$

Histogram to CDF

0	0	0	2	2
1	1	1	2	2
5	5	5	3	3
5	6	6	4	3
4	4	4	4	4

$5 \times 5\ matrix$

0	0	0	2	2
1	1	1	2	2
5	5	5	3	3
5	6	6	4	3
4	4	4	4	4

$5 \times 5\ matrix$

Pixel	No. of pixel	PDF	CDF
	3	$\frac{3}{25}$	$\frac{3}{25} = 0.12$
	3	$\frac{3}{25}$	$\frac{6}{25} = 0.24$
	4	$\frac{4}{25}$	$\frac{10}{25} = 0.4$
	3	$\frac{3}{25}$	$\frac{13}{25} = 0.52$
	6	$\frac{5}{25}$	$\frac{19}{25} = 0.76$
	4	$\frac{4}{25}$	$\frac{23}{25} = 0.92$
	2	$\frac{2}{25}$	$\frac{25}{25} = 1$

Histogram to CDF

$$\boldsymbol{Total\ pixels : 5 \times 5 = 25\ pixels}$$

Number of pixels	Probability	CDF
1	1/25 = **0.04**	0.04
2	2/25 = **0.08**	0.12
8	8/25 = **0.32**	0.44
10	10/25 = **0.40**	0.84
2	2/25 = **0.08**	0.92
1	1/25 = **0.04**	0.96
1	1/25 = **0.04**	1.00

Histogram to CDF

$$Total\ pixels : 5 \times 5 = 25\ pixels$$

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1	1/25 = **0.04**	0.04
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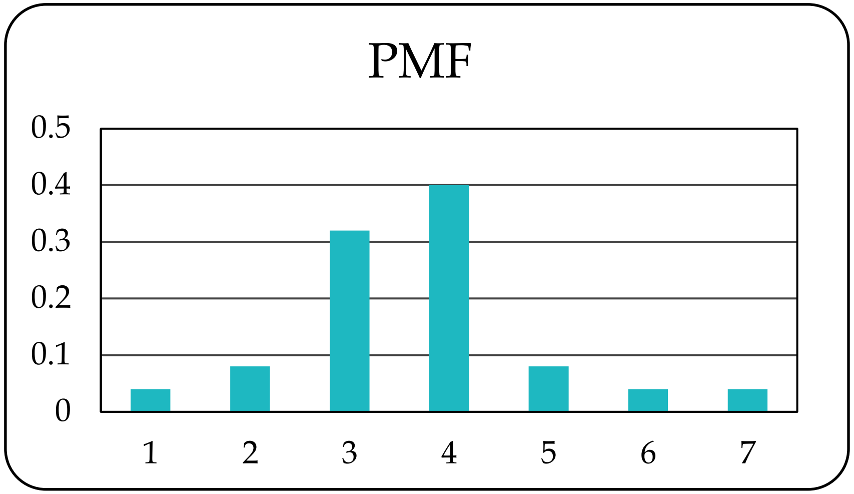
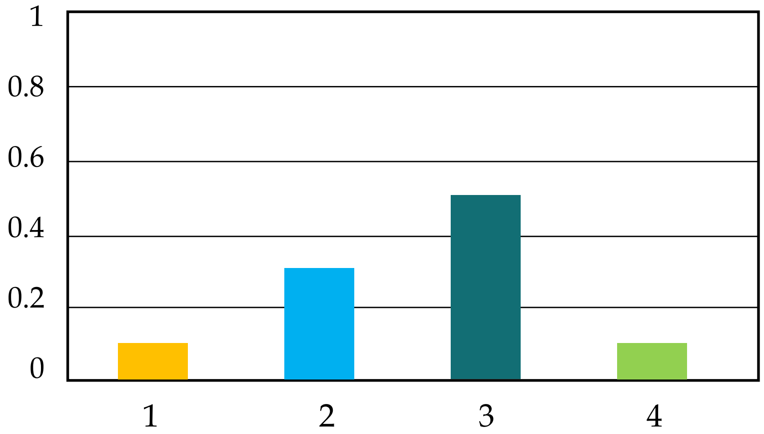
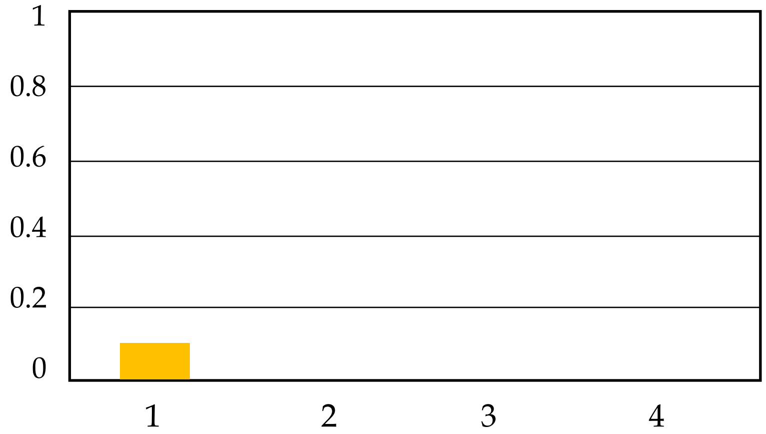
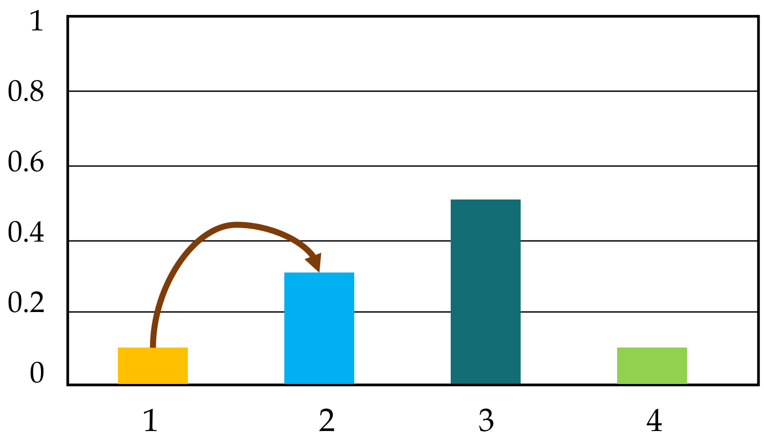


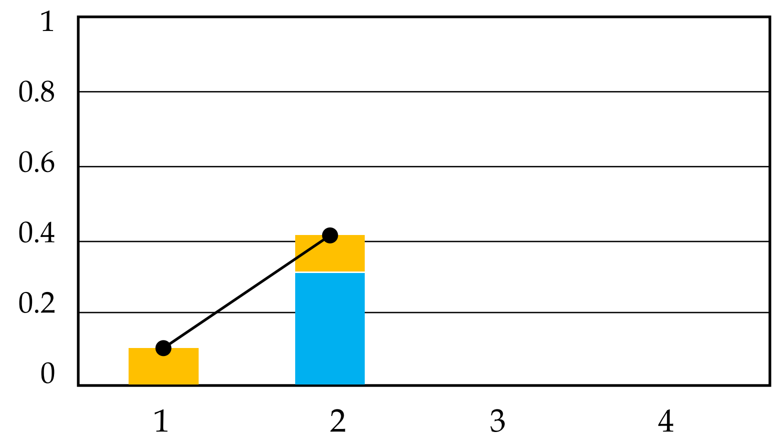
Histogram to CDF



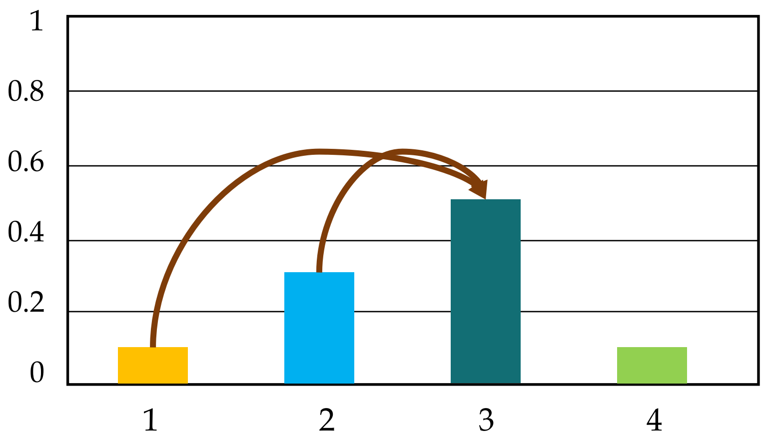


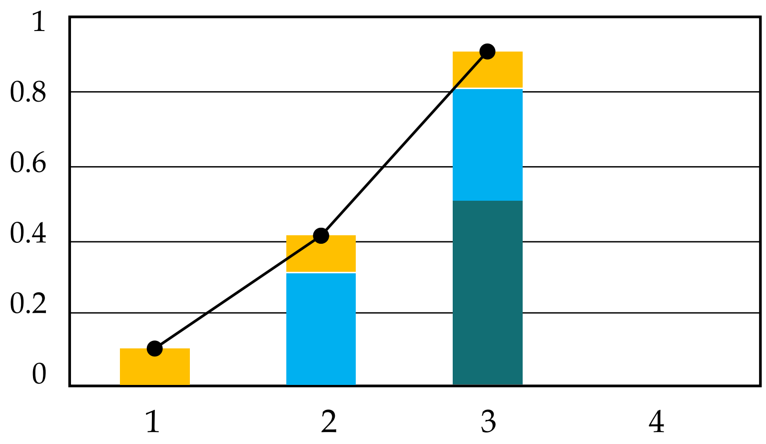
Histogram to CDF



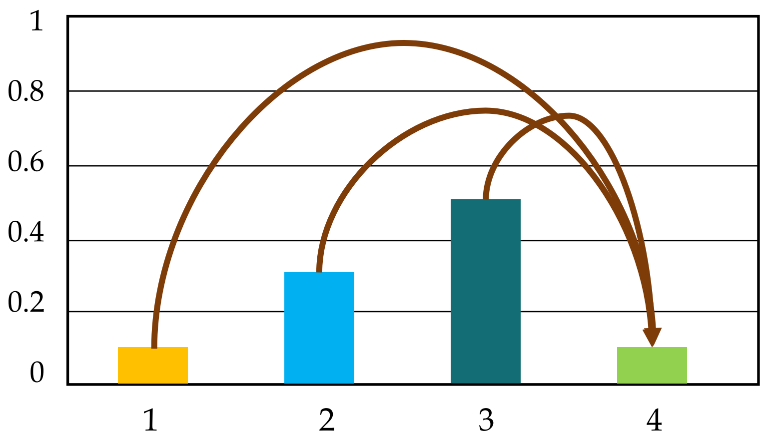


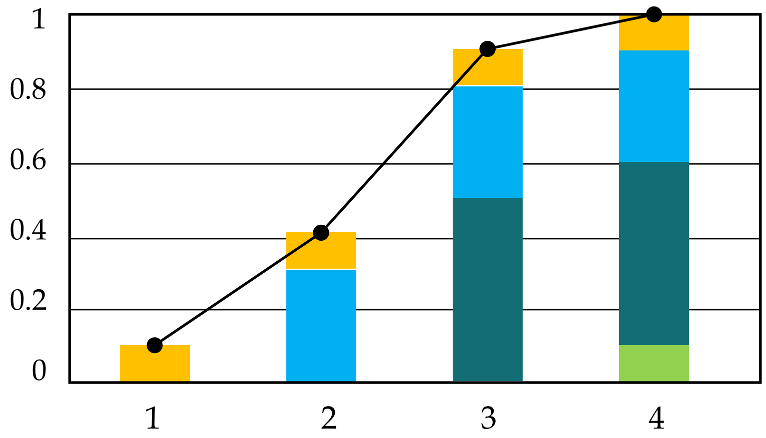
Histogram to CDF





Histogram to CDF





Histogram to CDF

$$\textit{Total pixels} : 5 \times 5 = 25 \textit{ pixels}$$

Number of pixels	Probability	CDF
1	1/25 = **0.04**	0.04
2	2/25 = **0.08**	0.12
8	8/25 = **0.32**	0.44
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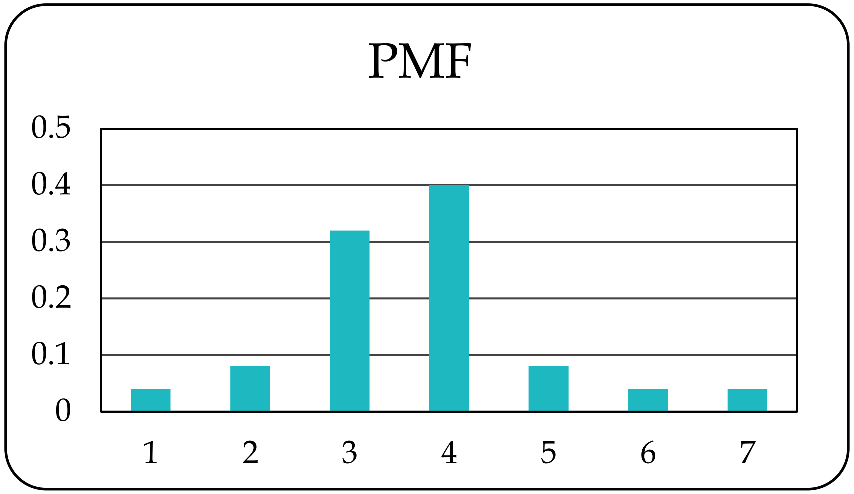
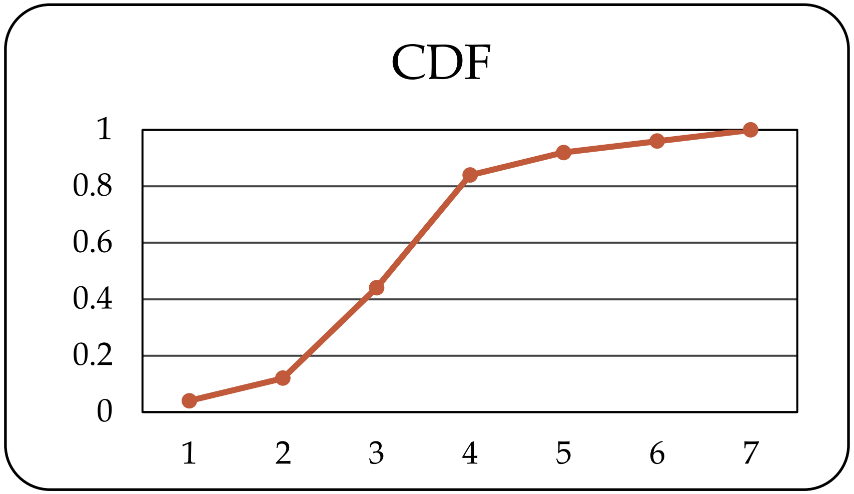
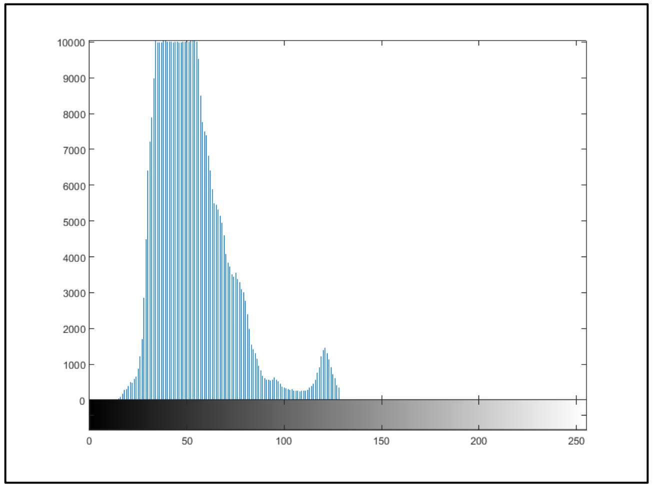




Histogram Equalization Example

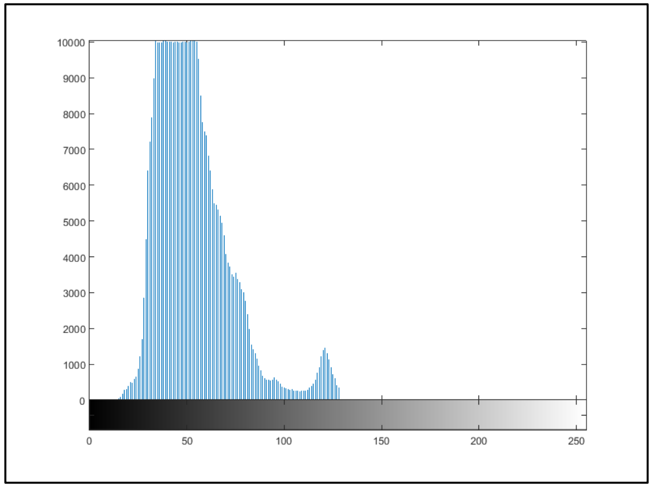
Original Image



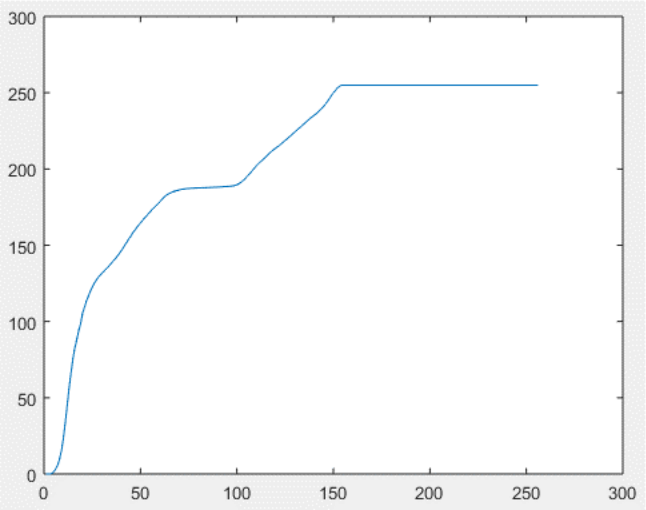
Histogram

Histogram Equalization

Original Image



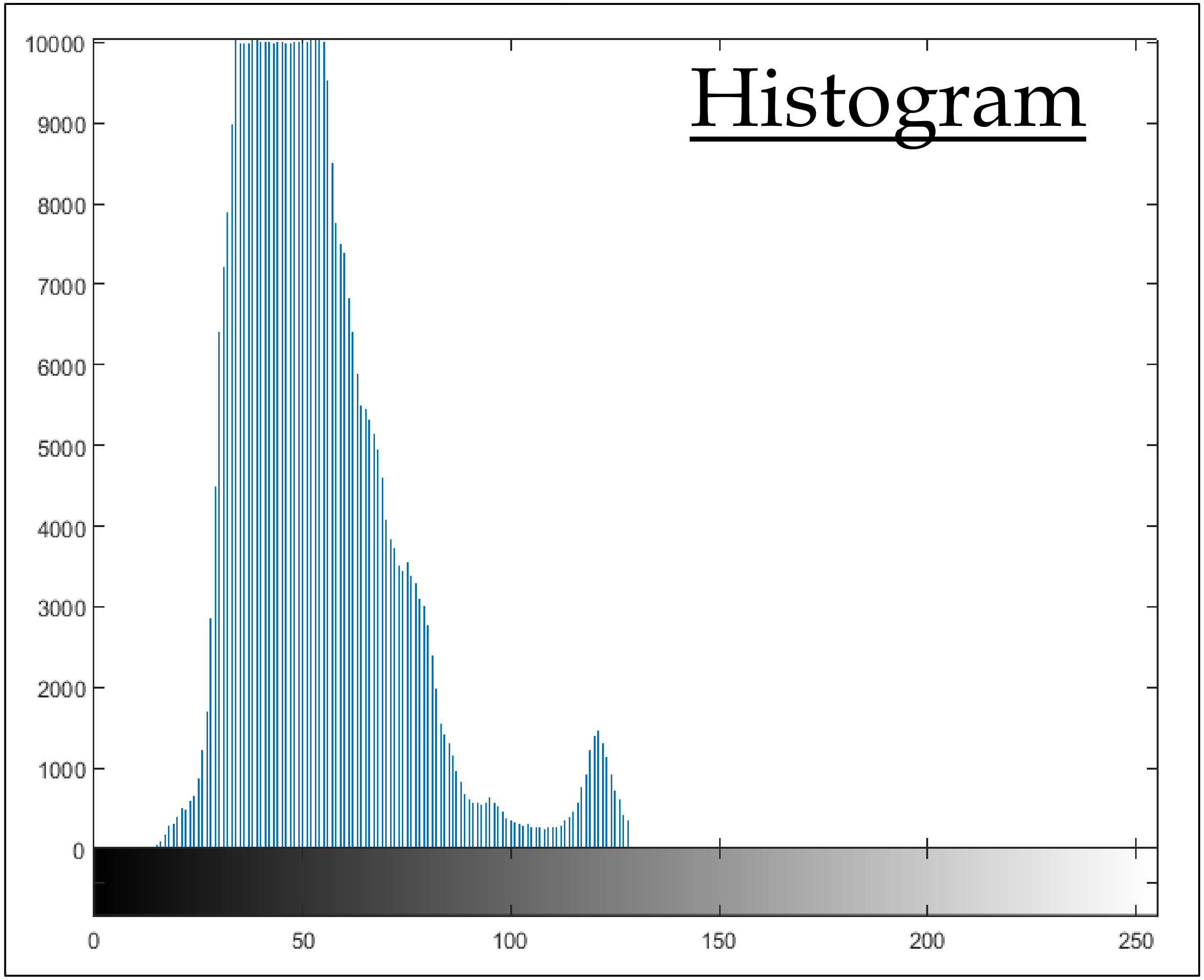
Histogram



CDF (Cumulative Density Function)

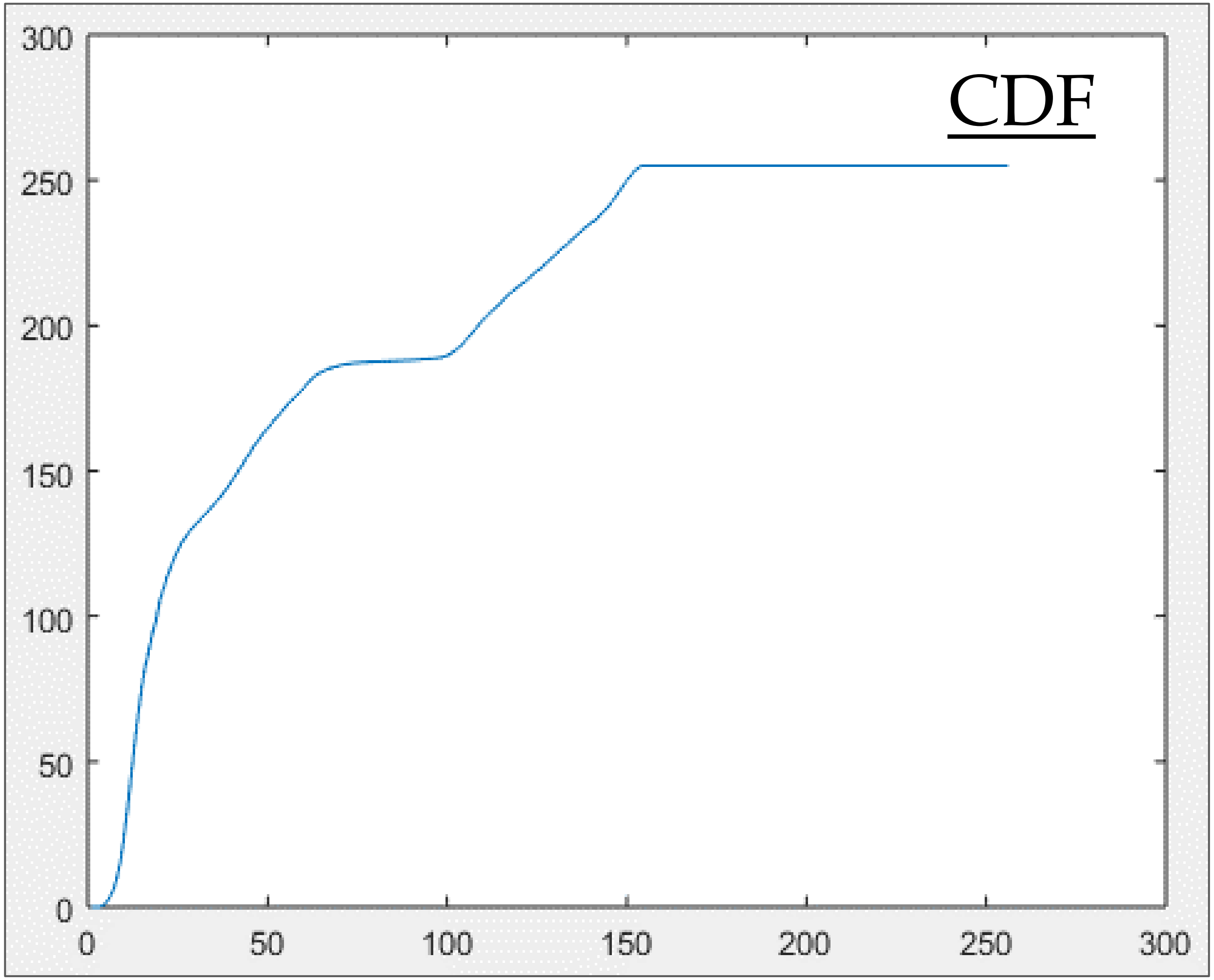
Histogram Equalization

Original Image



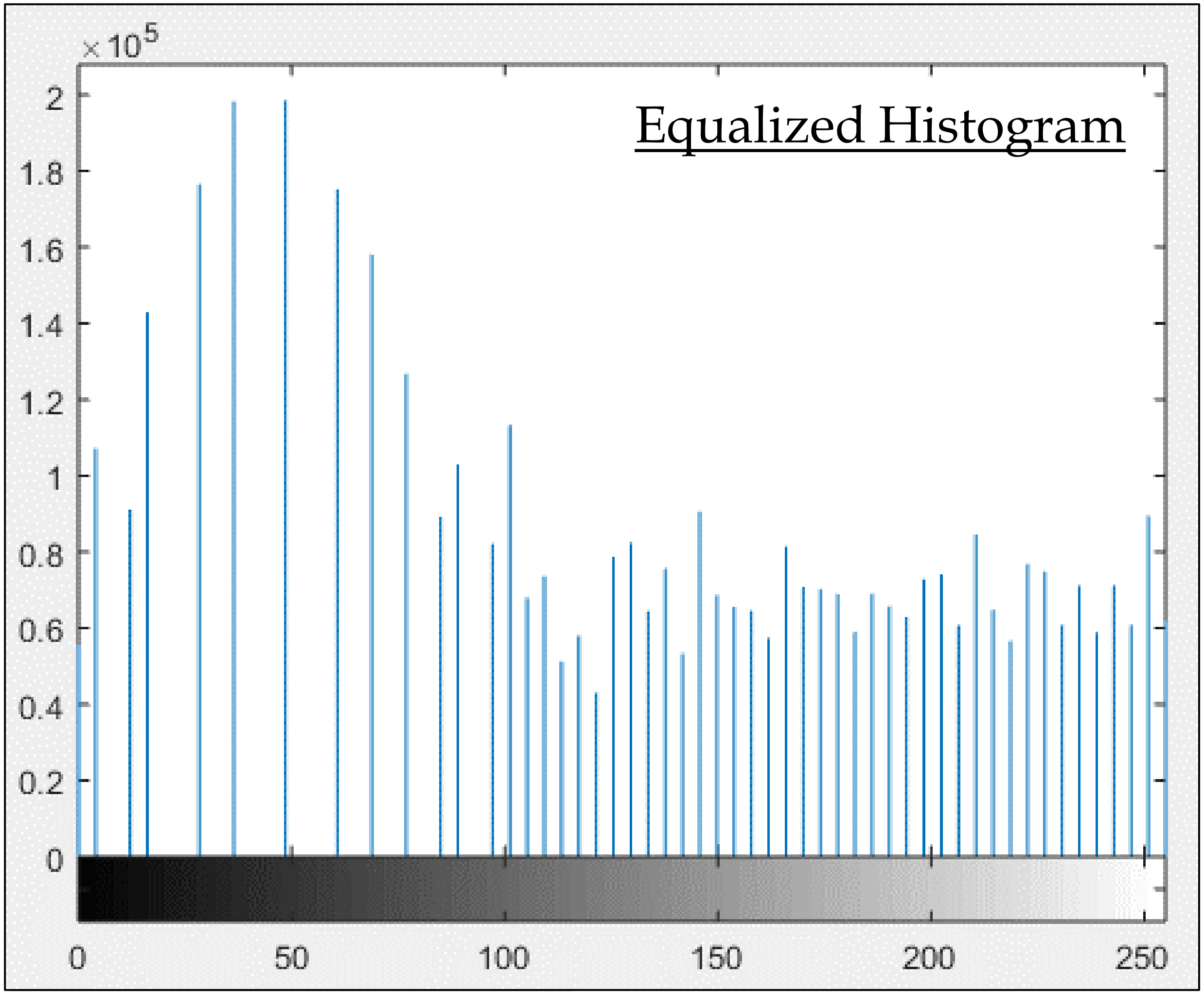
Histogram Equalization

Original Image



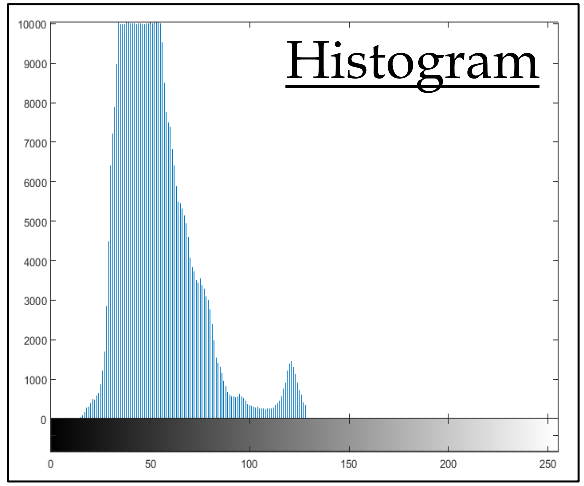
Histogram Equalization

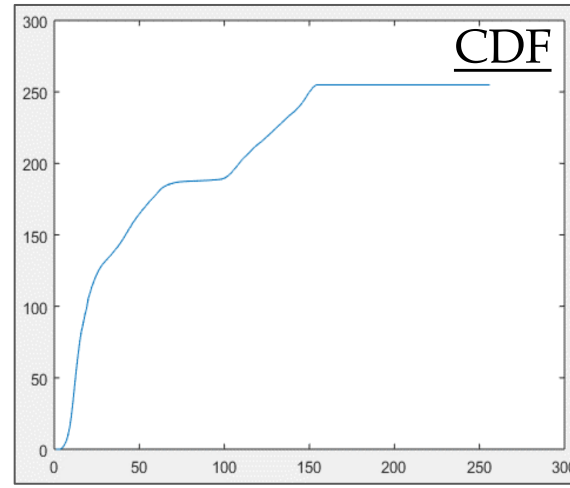
Original Image

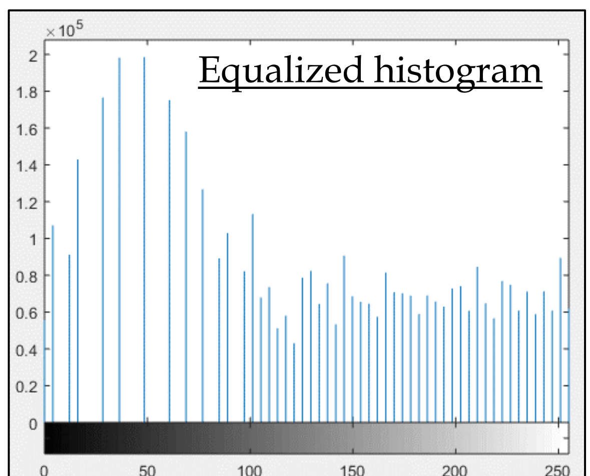


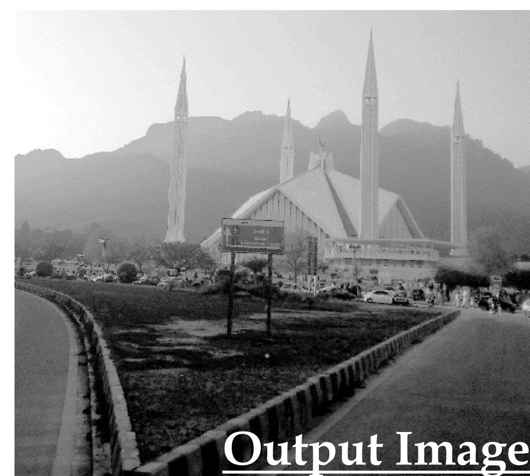
Histogram Equalization

Original Image

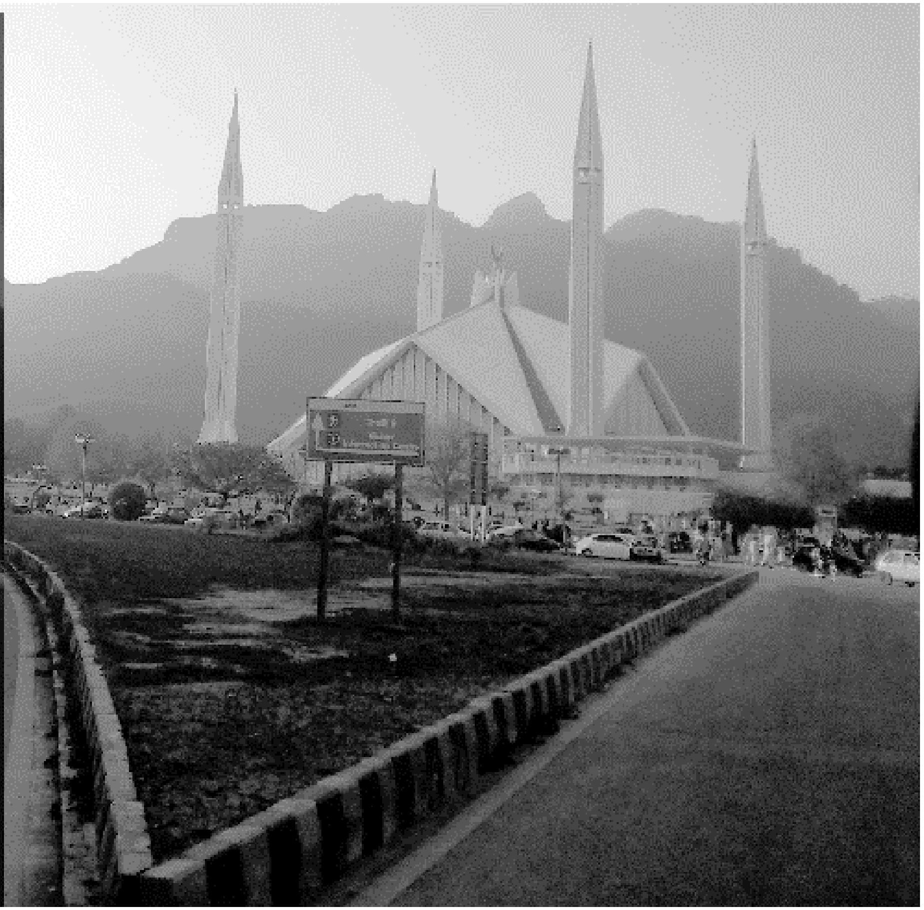




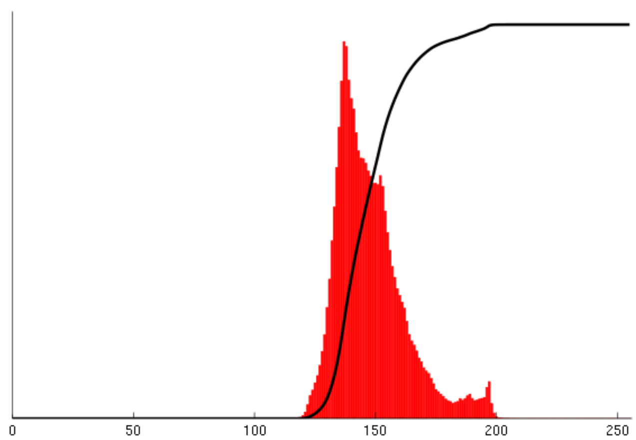


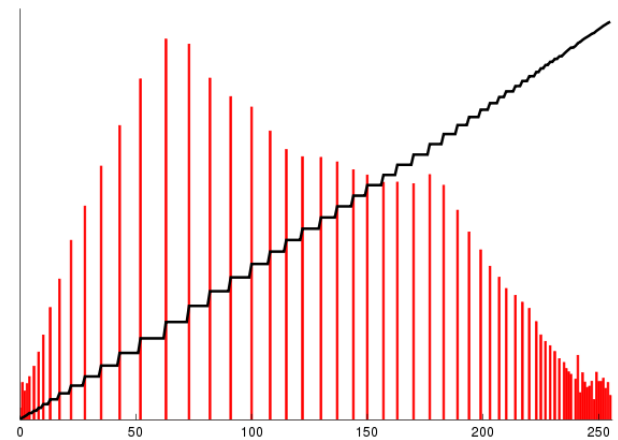


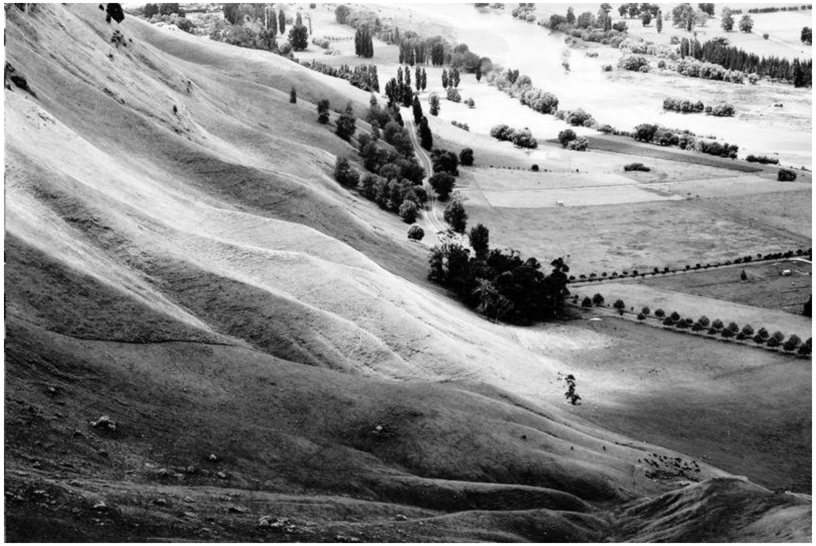
Histogram Equalization



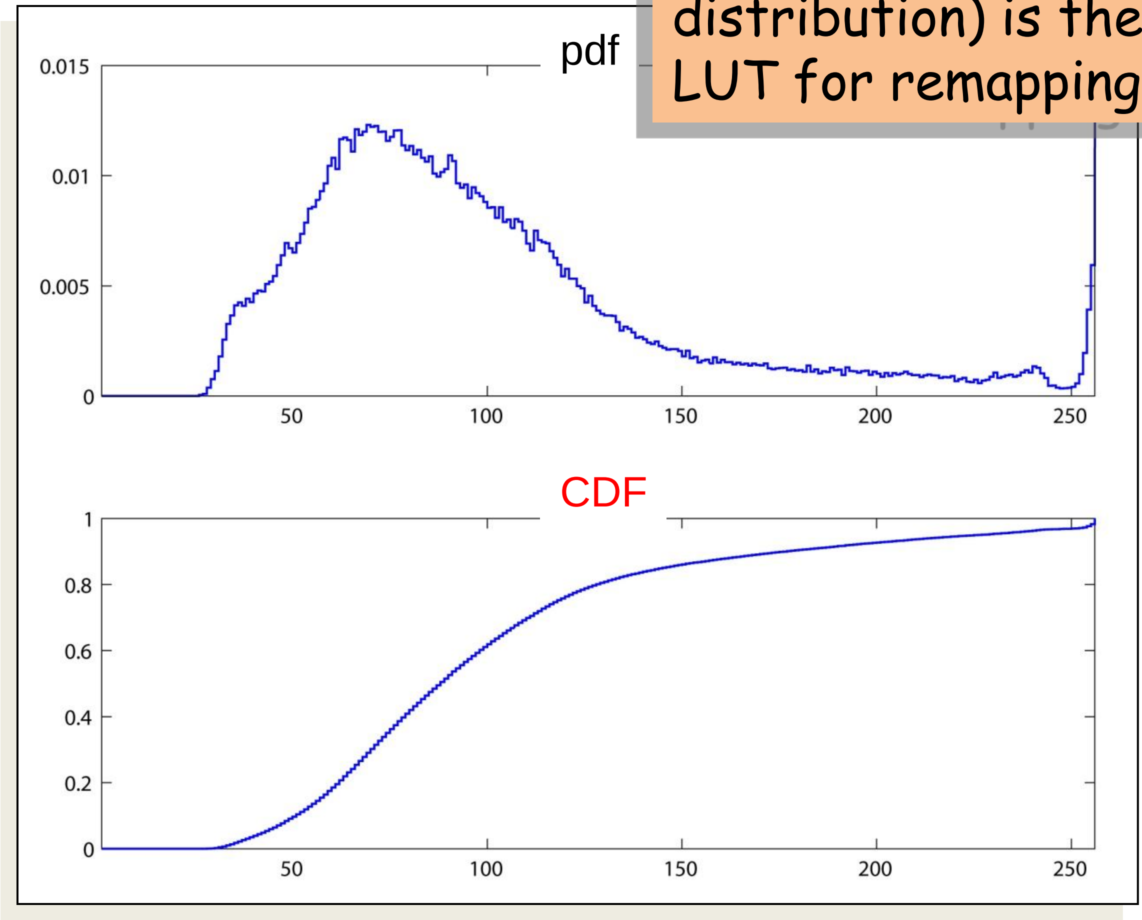
Histogram Equalization





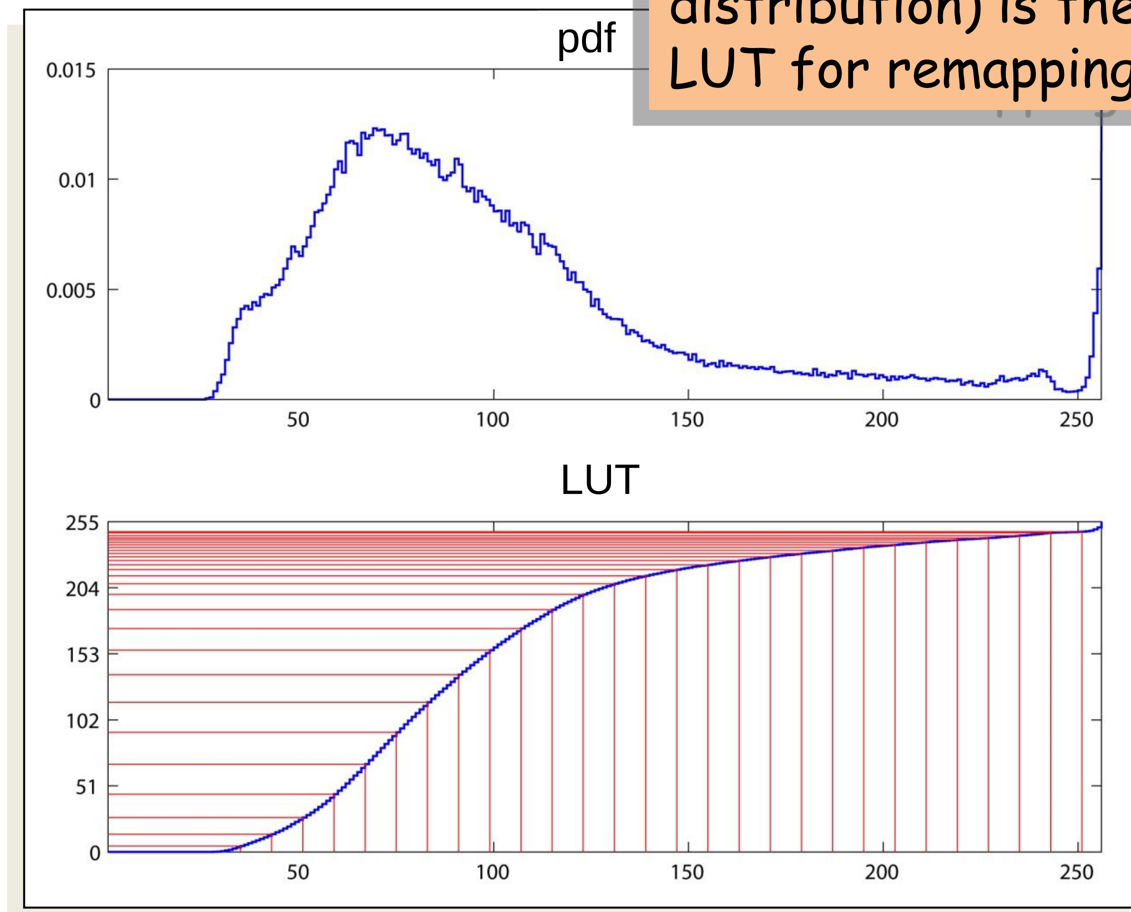


Histogram Equalization



The CDF (cumulative distribution) is the LUT for remapping.

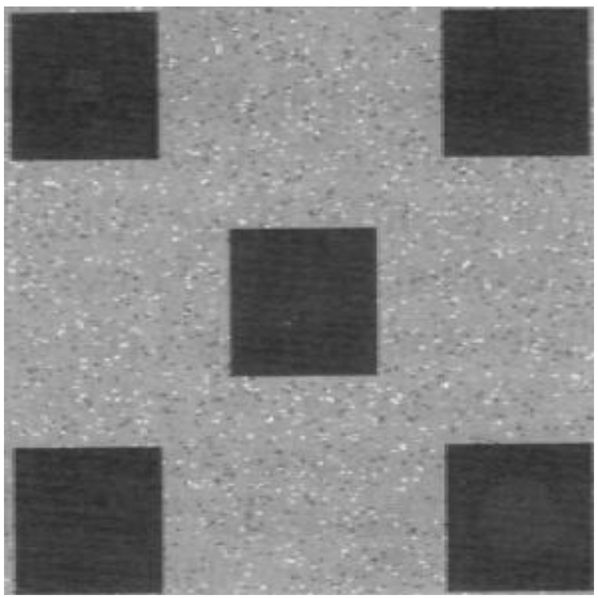
Histogram Equalization



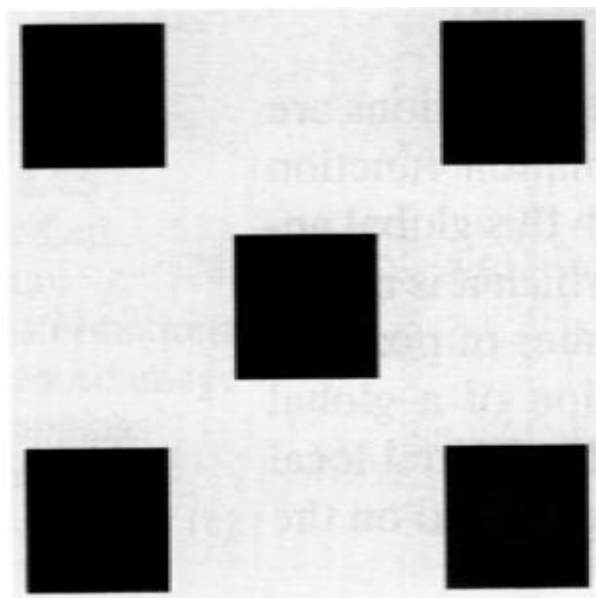
The CDF (cumulative distribution) is the LUT for remapping.

Histogram Equalization - Local

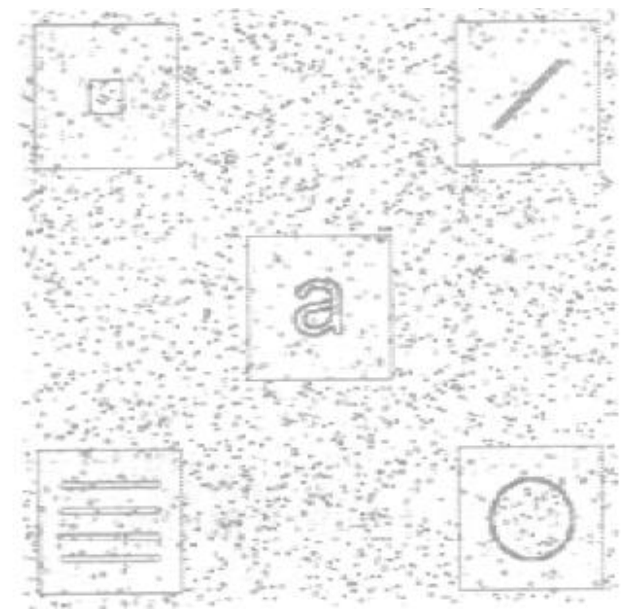
Original Image



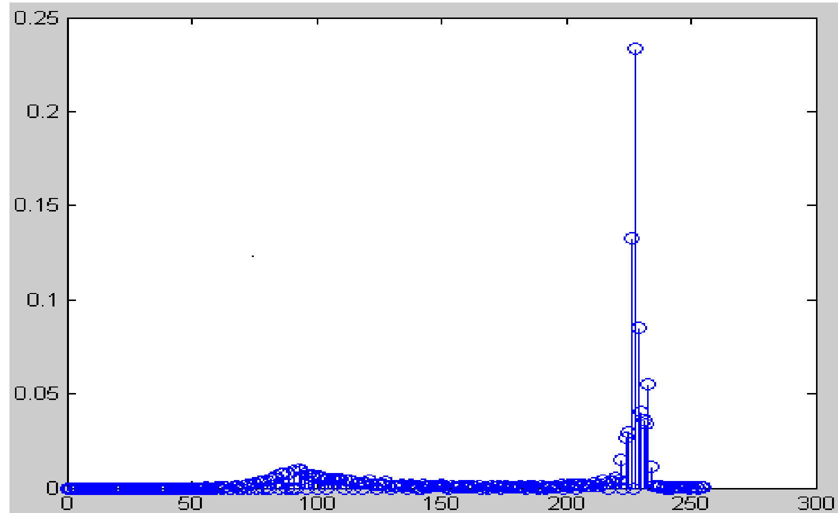
Global Equalization

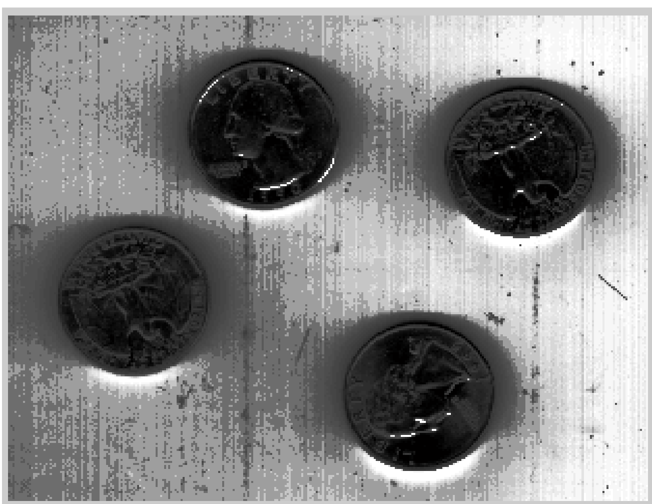


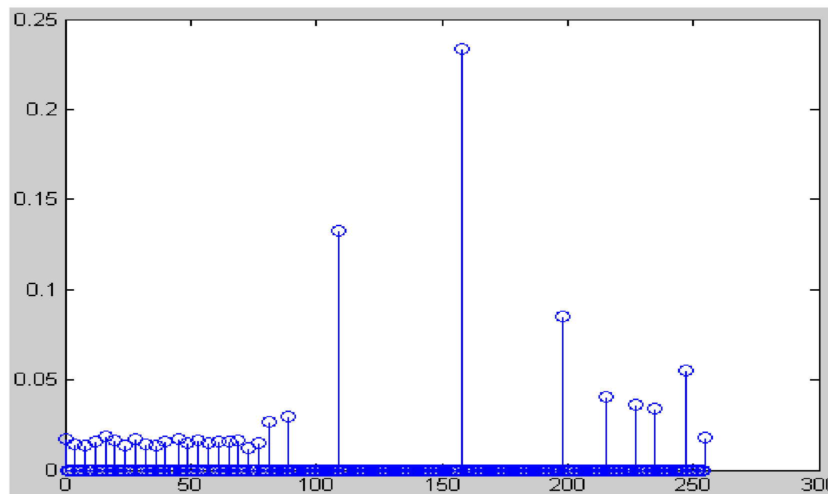
Local Equalization



Histogram Equalization - Problem







Problem with Histogram Equalization

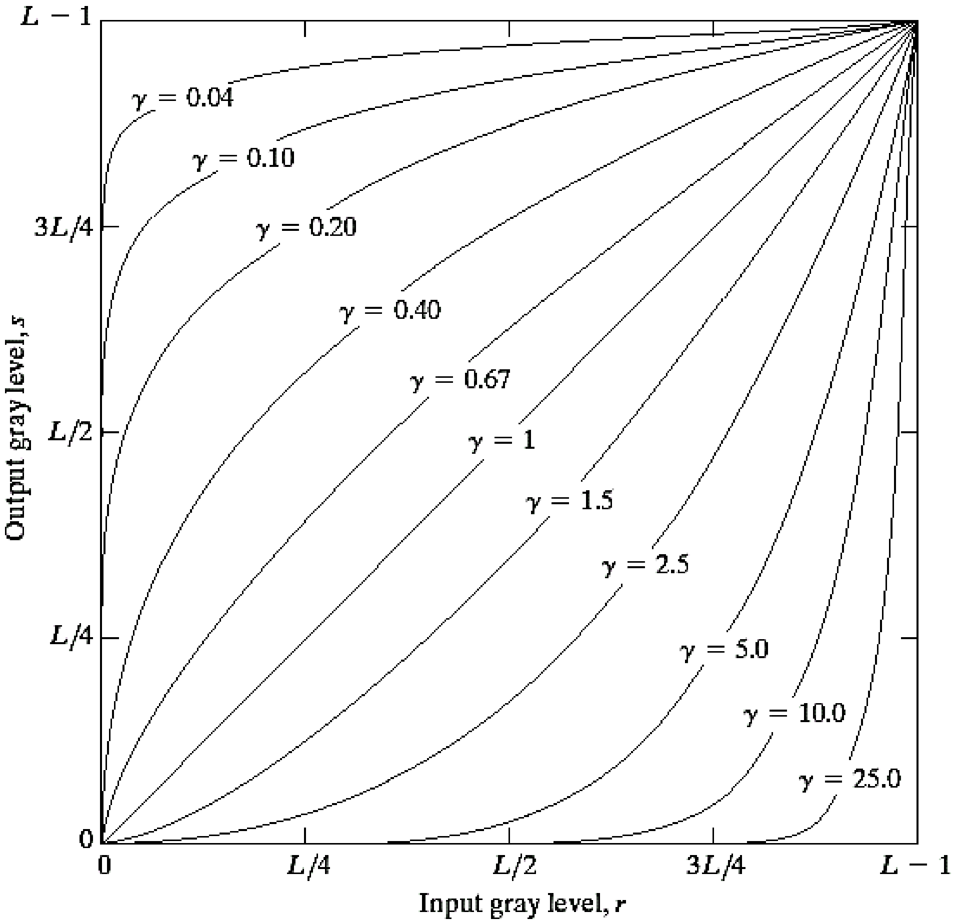
Power Law Transformations

- Power law transformations have the following form

$$s = c \times r^{\gamma}$$

- Map a narrow range of dark input values into a wider range of output values or vice versa

- Varying γ gives a whole family of curves



Power Law Transformations

- For g < 1: Expands values of dark pixels, compress values of brighter pixels
- For g > 1: Compresses values of dark pixels, expand values of brighter pixels
- If g=1 & c=1: Identity transformation (s = r)

- A variety of devices (image capture, printing, display) respond according to a power law and need to be corrected.

- **Gamma (g) correction**

  The process used to correct the power-law response phenomena.

Power Law Transformations

MR image of

human spine

Result after

Power law transformation

$\gamma = 0.6$

Result after

Power law transformation

$\gamma = 0.4$

Result after

Power law transformation

$\gamma = 0.3$

Power Law Transformations

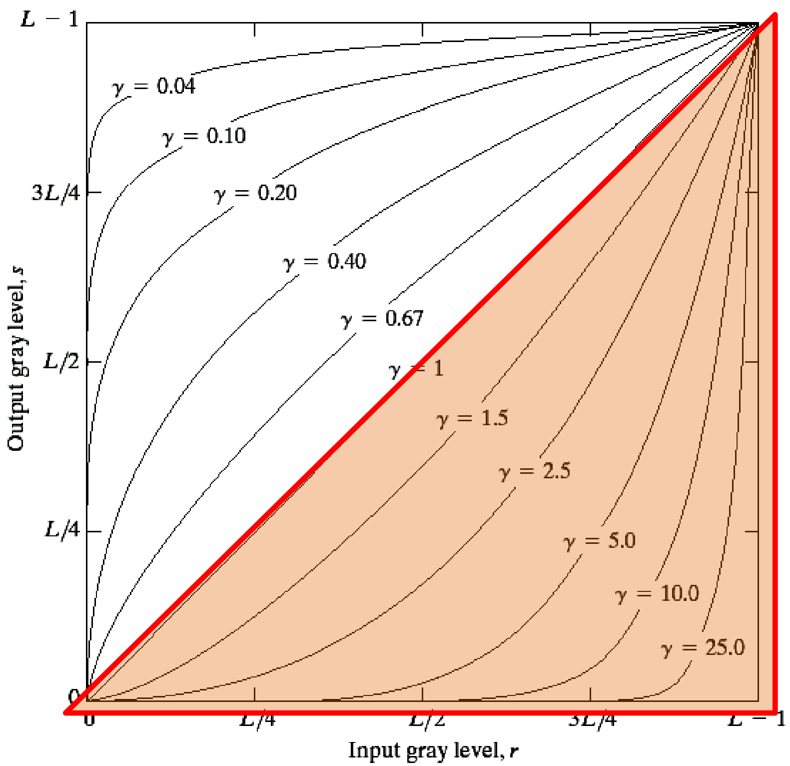
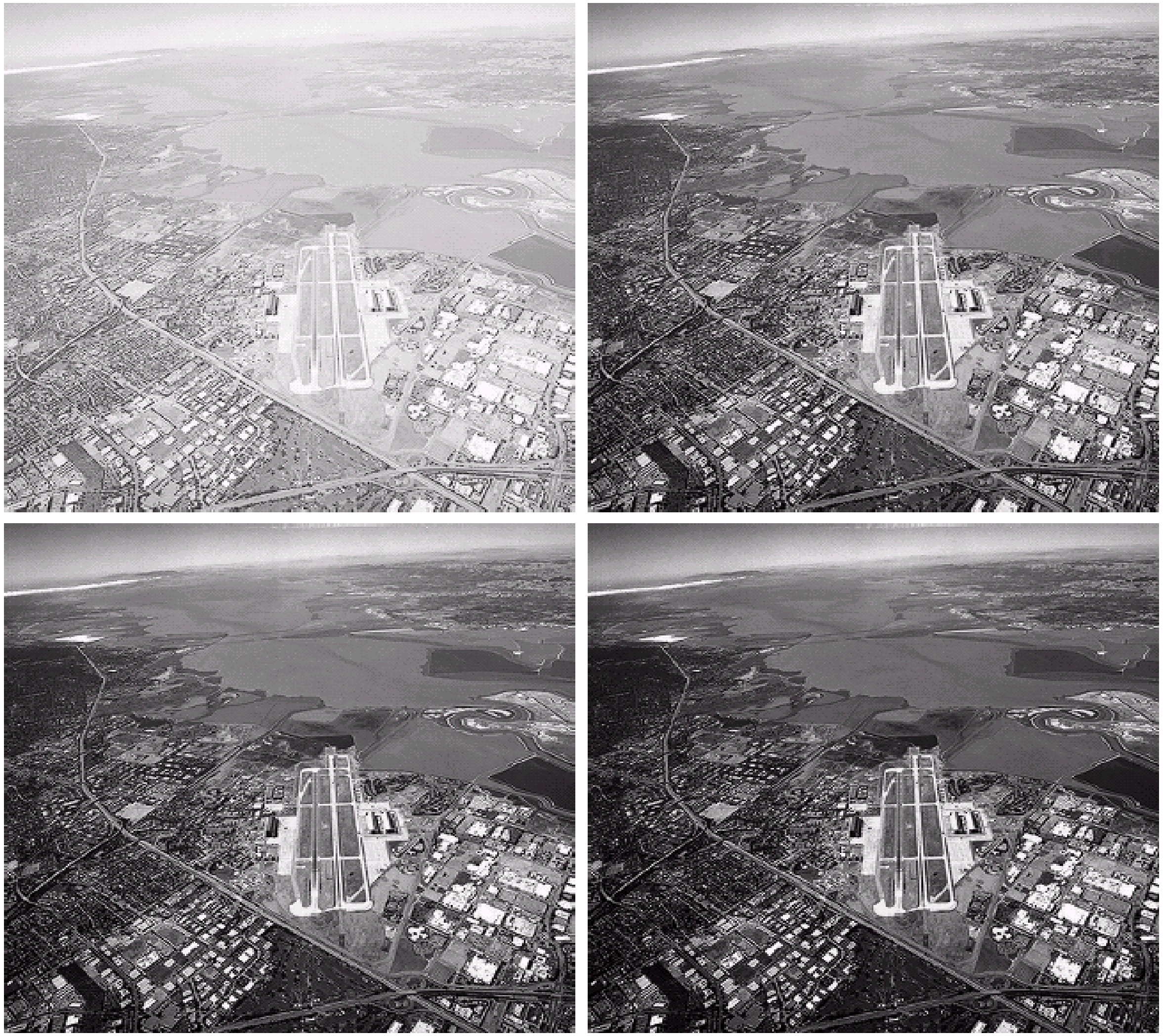


Image has a washed-out appearance – needs γ > 1

Power Law Transformations

Aerial

Image



Result of
Power law
transformation
$\gamma = 3.0$
(suitable)

Result of
Power law
transformation
$\gamma = 4.0$
(suitable)

Result of
Power law
transformation
$\gamma = 5.0$
(high contrast, some regions are too dark)

Logarithmic Transformations

- The general form of the log transformation is

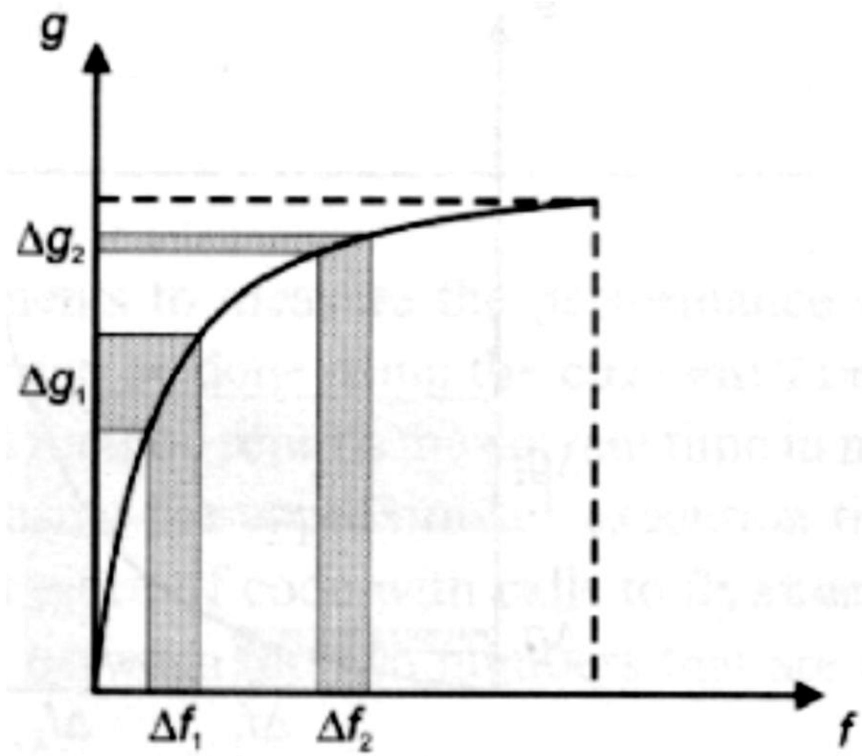
$$s = c \times \log(1 + r)$$

- The log transformation maps a narrow range of low input grey level values into a wider range of output values

- The inverse log transformation performs the opposite transformation

Logarithmic Transformations

- Properties
  - For lower amplitudes of input image the range of gray levels is expanded.
  - For higher amplitudes of input image the range of gray levels is compressed.



Intensity Transformations

Negative of an image?

Intensity Slicing?

Semester project

End

Intensity Transformations